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TEST AND EVALUATION OF AN ENROUTE SYSTEM TERRAIN-AVOIDANCE FUNCTION WITH THE NAS A3d2.1 SYSTEM

Frederick W. Ranger

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16. Abstract

This report describes the operational evaluation of an enroute system terrain-avoidance function in conjunction with the National Airspace System Enroute A3d2.1 system. Tests were conducted at the National Aviation Facilities Experimental Center, Atlantic City, New Jersey, in a low-altitude environment with simulated digital target data. Tests were designed to evaluate the performance of the terrain-avoidance function with respect to detection capability and adequacy of warning provided. Results indicate that although the terrain-avoidance function performed adequately for most enroute situations, false or late alerts could occur, due to the lag between the terrain-avoidance vector line and true aircraft heading. In most instances, the displayed information could be immediately and correctly interpreted by air traffic controllers and relayed to the pilots in adequate time for a safe response. Several functional changes made to the terrain-avoidance program to prevent problems encountered during testing were not subjected to detailed verification, thereby indicating a need for further testing of the function. Although these problems were encountered, the desirability of having a terrain-avoidance function as part of the enroute National Airspace System was not derogated.

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PREFACE

This report reflects the results of an effort at the National Aviation Facilities Experimental Center to test and evaluate an enroute system terrain-avoidance function in conjunction with the National Airspace System Enroute Stage A Model 3d2 system.

The operational program tape used throughout testing was developed for the A3d2.1 system. Discrepancies recorded were limited to the terrain-avoidance function and/or design in a simulated low-altitude environment. Results, conclusions, and recommendations contained in this report are operationally oriented and do not consider program size and processing time requirements as a function of the overall system, nor do they consider implementation-associated factors.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ABBREVIATIONS

ARTCC	Air Route Traffic Control Center
ARTS	Automated Radar Terminal System
CA	Conflict Alert
CDC	Computer Display Channel
CED	Computer Entry Device
CO	Terrain-Alert Display Suppression Message
DCC	Display Channel Complex
DEC	Data Entry Control
DSF	Digital Simulation Facility
DSS	Data Systems Specialist
E-MSAW	Enroute Minimum Safe Altitude Warning
FAA	Federal Aviation Administration
HSP	High-Speed Printer
IOT	Input/Output Typewriter
MSA	Minimum Safe Altitude
NAFEC	National Aviation Facilities Experimental Center
NAS	National Airspace System
PTR	Program Trouble Report
PVD	Plan View Display
RSB	Radar Sort Box
SAR	System Analysis Recording
SE	System Engineer
SSF	System Support Facility
STTA	Search Time For Terrain-Avoidance Parameter
UDS	Universal Data Set

INTRODUCTION

PURPOSE.

The purpose of this activity was to test and evaluate the operational suitability of an enroute minimum safe altitude warning (E-MSAW) function utilizing the model 3d2.1 program of the National Airspace System (NAS). This report discusses the method used and results obtained of the test and evaluation of the E-MSAW function conducted in the System Support Facility (SSF) at the National Aviation Facilities Experimental Center (NAFEC).

BACKGROUND.

The E-MSAW function, which provides the radar controller with a displayed warning of a potential collision between a tracked aircraft under his control and terrain and/or ground obstructions, was developed and built into the NAS Model A3d2.1 system, also containing the conflict alert (CA) function. This was done to make maximum use of, and to be consistent with, the logic of CA.

A series of program validation tests of the 3d2.1 program with E-MSAW was conducted in the SSF at NAFEC by ARD-140 personnel. Based on the favorable results of this testing, a series of operational system tests of the E-MSAW function was scheduled for conduct by NAFEC, ANA-110. The NAFEC operational system test activity was conducted between December 11, 1975, and June 23, 1976.

DISCUSSION

GENERAL.

Based on test procedures prepared by Federal Aviation Administration (FAA) personnel at NAFEC, a test team conducted tests in the SSF to evaluate the performance of the E-MSAW function in a simulated, low-altitude environment, with respect to detection capability and adequacy of warning provided.

The E-MSAW function is designed to provide early detection and warning of impending violation of terrain or obstruction clearance criteria by tracked aircraft. Altitude data for mode C and non-mode C tracked aircraft available from conflict alert processing are utilized to predict conflicts between an aircraft and the ground/obstruction. An adapted minimum safe altitude (MSA), based upon the terrain and obstructions, is compared with the path of each track projected for an interval of time, known as the "search time for terrain-avoidance parameter" (STTA), and a terrain alert is generated for aircraft which are determined to be too low, or are projected to become too low.

Two types of terrain alerts can be displayed to the controller, sort box alerts and obstruction alerts. A sort box alert indicates that an aircraft is projected during STTA to be within a radar sort box (RSB) whose MSA is higher than the current or projected altitude of the aircraft. The sort box

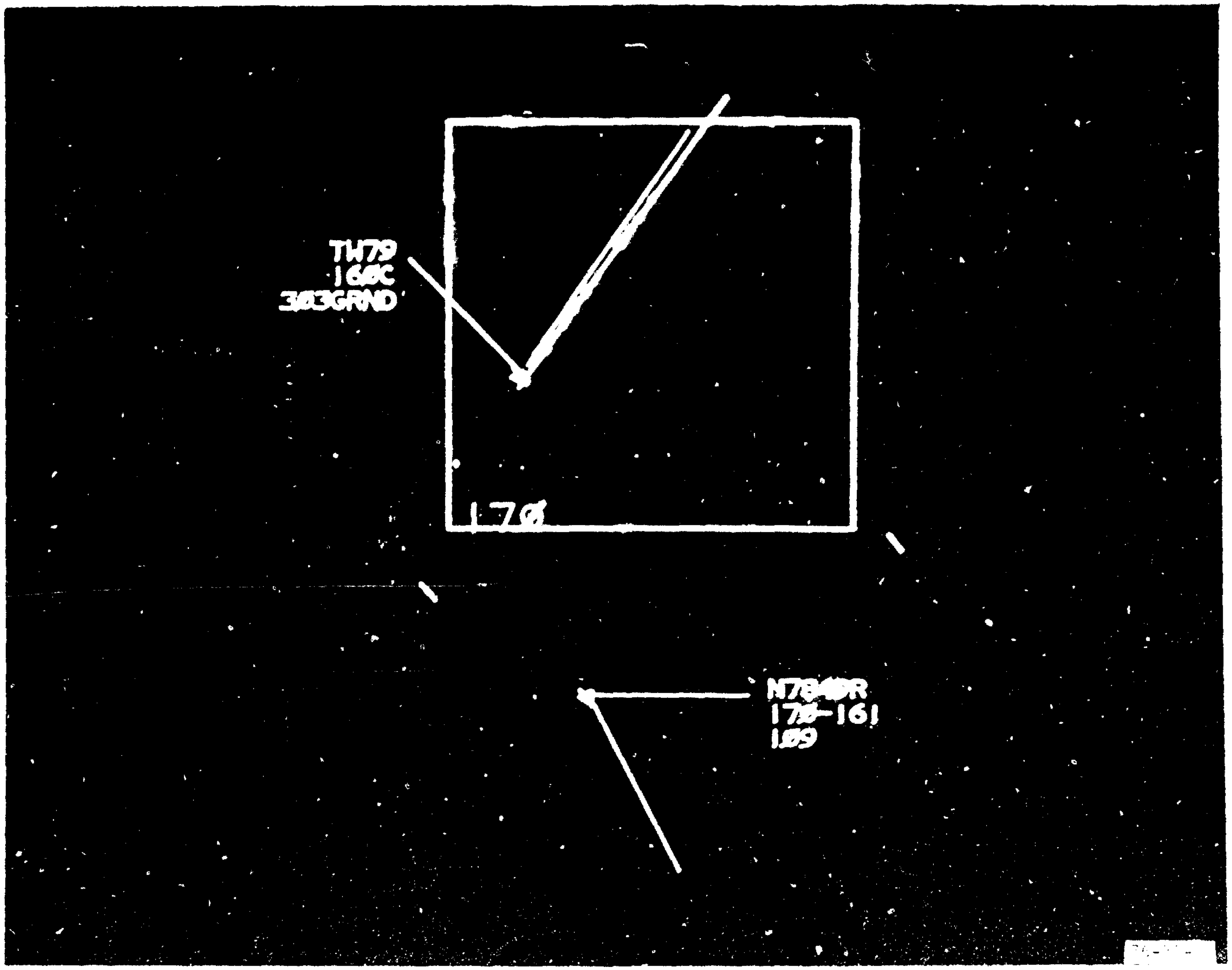

FIGURE 1.   SORT BOX ALERT

(16 nautical miles (nmi) square) is outlined on the controllers plan view display (PVD), and the MSA, blinking, in large-size characters, is displayed in the lower left corner of the RSB. A vector line representing the projected path of the aircraft during STTA is displayed, and the letters, "GRND," appears in field E of the full data block (figure 1).

An obstruction alert indicates that an aircraft is projected during STTA to pass too close to an obstruction whose MSA is higher than the present or projected altitude of the aircraft. An obstruction symbol and the safe altitude is displayed in large-size, blinking characters at the location of obstruction. As in the sort box alert, a vector is displayed, and GRND is displayed in field E of the full data block (figure 2). The letters, GRND, will not replace "EMRG" or RFOF," which mean emergency and radio failure, respectively. All alerts detected for an aircraft during STTA are displayed. Therefore, several sort box/obstruction alerts can be displayed simultaneously.

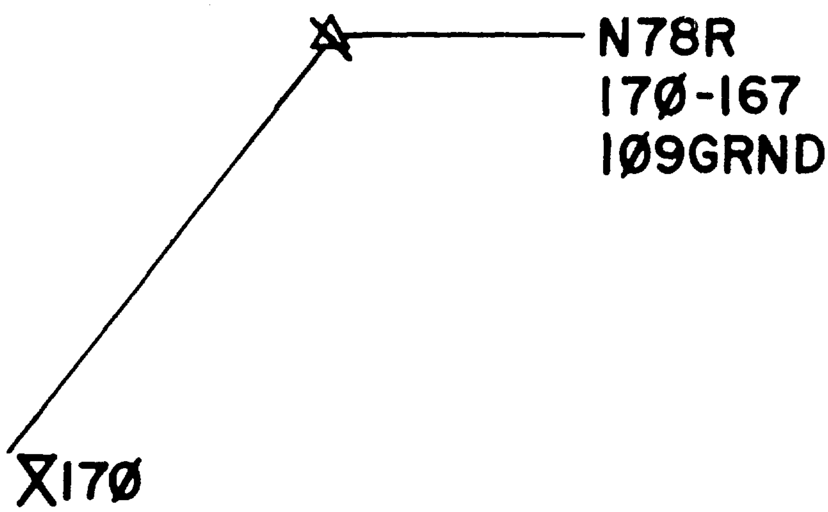

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FIGURE 2. OBSTRUCTION ALERT

For all test sessions at NAFEC, parameter STTA was kept constant at 150 seconds (2.5 minutes). In addition, the 34 obstacles adapted for testing were each assigned a 5-nmi radius of protected airspace. The MSA for obstacles varied from 6,000 feet, as the lowest, to 17,500 feet as the highest. The MSA for sort box adaptation varied from 1,300, as the lowest, to 17,000 as the highest. All tests involved participation of NAFEC controllers, digital simulation facility (DSF) personnel, and personnel from NAFEC to perform observer, data systems specialist (DSS), and system engineer (SE) duties.

Thirty-eight operational system tests were conducted between December 11, 1975, and June 23, 1976. During this time frame, five versions of the E-MSAW function, identified as TAV001, TAV002, TAV003, TAV004, and TAV005 were tested. Prior to operationally testing each version, a minimum of two shakedown tests were conducted to verify stability of the new version. The appendix contains a summary of all test sessions (shakedown and operational) conducted.

ENVIRONMENT.

All test sessions were conducted in the SSF, a laboratory model developed at NAFEC for enroute system testing (figure 3). The SSF is divided into two 12-sector laboratories, each one differing only in equipment used to drive the displays. These include the computer display channel (CDC) and the 9020E display channel complex (DCC). Tests could be and were conducted using either configuration.

Each version of the E-MSAW function was built into the CA2111 system, which is an A3d2.1 A3DL055 NAS system that includes version 11 of conflict alert. The addition of the E-MSAW function to that system did not change the functional characteristics of conflict alert in any way. For the CDC laboratory, CDC version 38F8 was used, and for the DCC laboratory, the DCC version 507Y was utilized.

Sector configuration was identical in both laboratories and was based upon a hypothetical air route traffic control center (ARTCC) geography known as the universal data set (UDS). Of the 12 sectors available, the 7 low-altitude enroute sectors (sectors 1, 2, 3, 4, 5/6, 7/8/9, and 10/11) were utilized for test sessions.

Simulated radar inputs to the SSF were provided by the DSF for 6 of the 12 radar sites adapted for the UDS.

One traffic sample was utilized during testing. Air traffic flow, density, types of aircraft, and equipment were relatively realistic to that encountered in a live environment. The sample was a mix of enroute, departures and arrivals, and provided a 2-hour period of air traffic control situations. In addition, preplanned terrain/obstacle conflicts and aircraft/aircraft conflicts were programmed into the traffic sample. All traffic movement was limited to the low-altitude airspace (flight level 230 and below).

METHODOLOGY

GENERAL.

To test and evaluate the E-MSAW function with respect to detection capability and adequacy of warning provided, five major areas of evaluation were selected and remained constant throughout testing. The areas of evaluation included

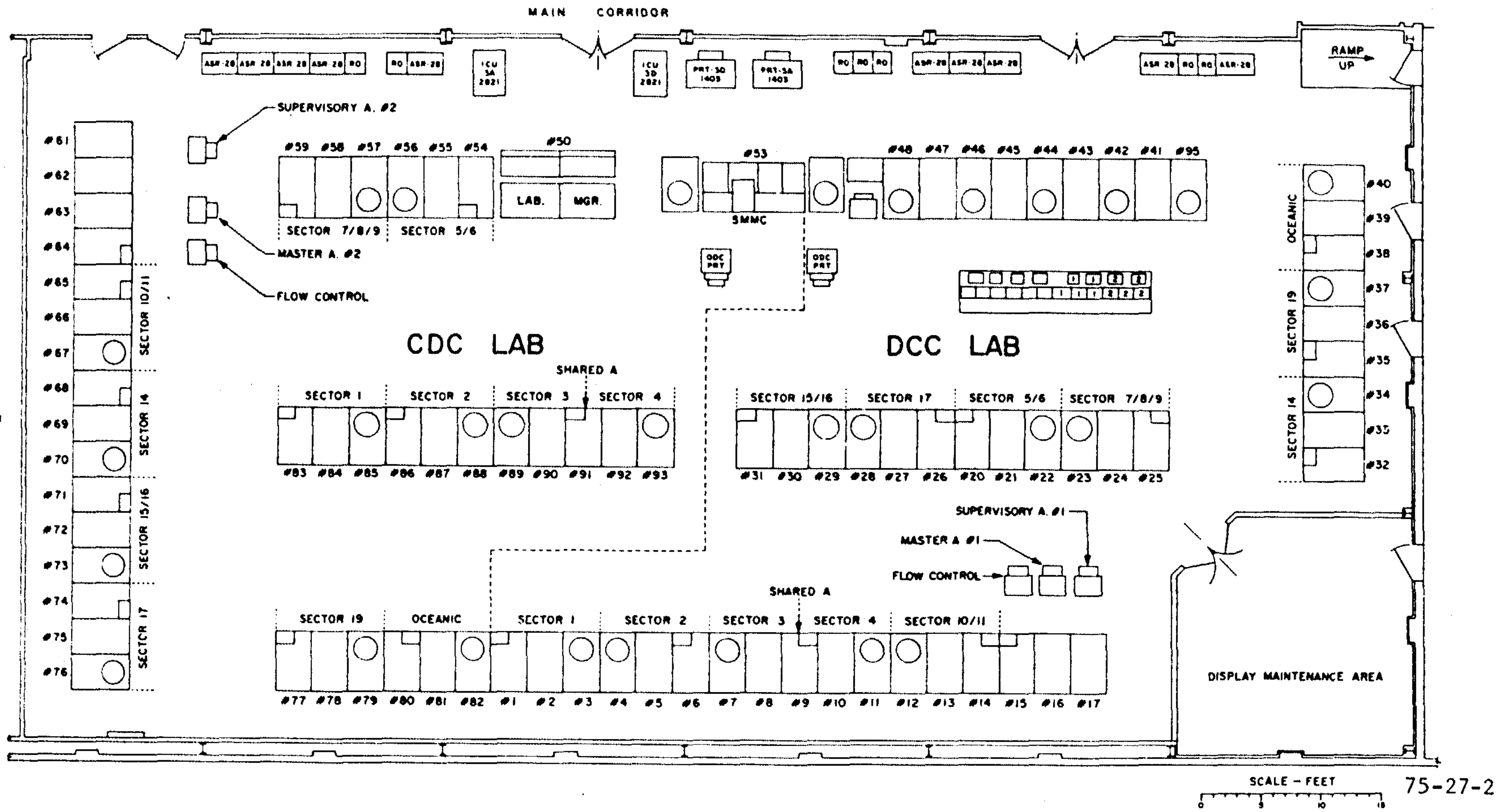

FIGURE 3. SYSTEM SUPPORT FACILITY LABORATORY CONFIGURATION

(1) overall performance of detection/alert, (2) timeliness of the alert, (3) false alert occurrences, (4) attention-getting suitability, and (5) quality of the displayed information and alert.

The DSF, according to a preplanned traffic sample, was used to generate target movement on specific routes with associated flight plans (taped inputs). Approximately 228 aircraft were tracked during each 2-hour test period. Each test period was comprised of operational air traffic control situations in a sterile test environment; i.e., no code garbling, no radar noise, no jitter.

Throughout testing, controllers and observers were asked to record any discrepancies in the performance of the E-MSAW function, the A3d2.1 program with E-MSAW, or the conflict alert function working in combination with the A3d2.1/E-MSAW function. Observers were also asked to record false alerts, alerts generated too soon, and/or alerts generated too late.

During test sessions, specific sectors were selected to test certain situations that were not included in the traffic sample. These situations included descent below assigned altitude, turns into and away from unsafe areas, multiple aircraft in the same sort box, multiple aircraft toward the same obstacle, descents on obstacles, climbs into obstacles, priorities of codes 7700 and 7600 over GRND in data blocks, use of the suppression logic, and turns toward a sort box already displayed for another aircraft. In addition to these situations, which were repeated numerous times, all input/output typewriter (IOT) messages associated with the E-MSAW function were exercised at various times during test sessions.

As the E-MSAW implementation (into the NAS system) was to make maximum use of and to be consistent with the logic of conflict alert, situations were developed to determine if any problems existed when both functions were activated for the same aircraft. Controllers and observers were asked to record any degradation of either function during saturation-type tests.

DATA COLLECTION.

Manually collected data recorded by observers, controllers, and debriefing sessions were used as the basis for analysis of test results. Terrain alert printouts, conflict alert printouts, and automatic data collected on the system analysis recordings (SAR) were used in conjunction with the manually collected data.

RESULTS

Results were based on (1) debriefing sessions that followed each test session, (2) test observer logs, (3) analysis of online printouts, and (4) scrutiny of the data reduction and analysis printouts obtained from the automatic data collected on the system analysis recordings. The major emphasis in conducting E-MSAW testing was placed on assessing the performance of the A3d2.1 E-MSAW function with respect to detection capability and adequacy of warning provided.

Five versions (TAV001 through TAV005) of the E-MSAW function were evaluated during this test effort. Although controller response to the E-MSAW concept was favorable throughout testing, the first three versions were considered to be unsatisfactory from an operational standpoint. This unsatisfactory condition was caused, in part, by the high rate of "false alarms" being generated during testing. A total of 39 program trouble reports (PTR's) were written against the first three E-MSAW versions. The majority of the PTR's concerned false alerts. Additional problems encountered with TAV001, TAV002, and TAV003 included overriding EMRG and RDOF priorities, failure to detect and generate an alert (isolated cases), and erratic display of information in field E of the full data block.

With release of TAV004 and TAV005 came a more stable E-MSAW program and corrections to problem areas encountered in previous versions. Although the latter two releases were not error free, controllers agreed that the problems encountered did not derogate the desirability of having the E-MSAW function as a part of the enroute NAS program.

The timing of the appearance of the displayed information (sort box/obstacle, flashing altitude, and GRND) was considered adequate for most situations; i.e., the alert was displayed in time for the controller to alert the pilot and for safe response.

With some minor exceptions, the performance of the E-MSAW function was found to be adequate for enroute aircraft. However, controllers agreed that major problems (false alerts and clutter) could exist when, (1) aircraft were departing from or arriving at airports having no approach control service or automated radar terminal system (ARTS) service, (2) track control is retained by the ARTCC, and (3) these airports are not precisely defined as terminal areas in adaptation. A functional change for TAV005 was designed to prevent this problem; however, due to time limitations, the change was not subjected to detailed testing for verification.

Additional problems with arriving aircraft occurred when the airport of intended landing was between the aircraft position and an obstacle beyond the airport, but within STTA minutes of flying time. The STTA projection beyond the airport generated an obstruction alert which the controller considered false and distracting. Again, a functional change to prevent this type of problem could not be tested due to time limitations.

The STTA projection can also cause alerts to be generated for aircraft cleared to hold at a fix which has terrain and/or an obstruction with a higher MSA than the aircraft altitude beyond it and the aircraft has not yet reached the point where the track is dropped.

In addition to the possible false alerts generated by arriving/departing aircraft, false alerts and late alerts can be generated by enroute aircraft. The majority of these false/late alerts can be attributed to the lag in the terrain-avoidance vector line. To compound the problem, the terrain-avoidance vector

Throughout testing, all E-MSAW-associated inputs were exercised. The inputs were made dynamically from the computer entry device (CED), the data entry control (DEC), and the IOT. No inputs were exercised from the card reader. All output for the associated input was as specified.

During several test sessions, short periods of time were devoted to terrain alert storage saturation. In conjunction with the terrain alert saturation, controllers vectored aircraft into conflict to determine the impact, if any, that this saturation would have on the conflict alert program. There were no reports or observations of degradation of either the NAS system or the conflict alert function once terrain alert storage saturation was attained (indicated by the IOT output message, "WARNING--TERRAIN ALERT STORAGE SATURATED").

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CONCLUSIONS

From analysis of all the data collected, it is concluded that:

1. With respect to detection capability and adequacy of warning provided, although the E-MSAW function performed adequately for most enroute situations, late or false alerts can be expected due to the lag between the terrain avoidance vector line and the true aircraft heading.

2. For arriving and departing aircraft, false alerts and an increase in clutter can be expected unless non-approach-control-serviced airports are precisely defined as terminal areas in facility adaptation.

3. Inclusion of the E-MSAW function into the A3d2.1 conflict alert system did not degrade the performance of the CA function.

4. In certain instances, displayed information can be difficult to interpret or can be misinterpreted.

5. Discrepancies between information displayed to the controller and information printed out on the HSP during the generation of terrain alerts can occur.

RECOMMENDATIONS

Predicated on the results and the conclusions derived from these tests of the E-MSAW function, the following recommendations are presented:

1. Conduct further E-MSAW testing at NAFEC to optimize display information, parameter values, and verify functional changes to the program currently available or as added in the future.

2. Refine the E-MSAW program design so that it makes use of flight plan information to reduce false or late alerts for aircraft nearing an expected turn.

3. Improve the track azimuth and track position prediction process to more closely reflect true aircraft heading in order to reduce false or late alerts for vectored aircraft.

4. Following the above, conduct a period of field evaluation tests of the E-MSAW function, leading to possible implementation into the enroute NAS.